MAVIS: Mobile Acquisition and VISualization - A Professional Tool for Video Recording on a Mobile Platform

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Figure 1: *User interface of MAVIS on an iPhone6*

Abstract

Professional video recording is a complex process which often requires expensive cameras and large amounts of ancillary equipment. With the advancement of mobile technologies, cameras on mobile devices have improved to the point where the quality of their output is sometimes comparable to that obtained from a professional video camera and are often used in professional productions. However, tools that allow professional users to access the information they need to control the technical quality of their filming and make an informed decision about what they are recording are missing on mobile platforms. In this paper we present MAVIS (Mobile Acquisition and VISualization) a tool for professional filming on a mobile platform. MAVIS allows users to access information such as colour vectorscope, waveform monitor, false colouring, focus peaking and all other information that is needed to produce high quality professional videos. This is achieved by exploiting the capabilities of modern mobile GPUs though the use of a number of vertex and fragment shaders. Evaluation with professionals in the film industry shows that the app and its functionalities are well received and that the output and usability of the application align with professional standards.

CR Categories: I.3.8 [Computer Graphics]: Applications

Keywords: Image and Video Processing, Film-making on mobile devices

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1 Introduction

Professional video recording is a complex process which often requires the use of professional video cameras and large amounts of ancillary equipment, as shown in figure 2. This large amount of technology is expensive, cumbersome to transport and difficult to carry when filming on location. By contrast mobile devices allow the creation of quick dynamic shots that the professional equipment can't due to its size.

Figure 2: *Kit used for filming: camera, recorder, waveform monitors, colour vectorscope, preview monitor, focus peaking monitor and false colour monitor (anonymized for review purposes)*

With the advancement of mobile technologies cameras on mobile devices have improved to the point where the quality of their output is sometimes comparable to that obtained from a professional video camera. Moreover mobile cameras are being used more and more frequently in professional production environments. In terms of resolution most cameras in high-end smart-phones are capable of recording videos in HD, or even 4K, by using dedicated apps [Uriostegui 2014], and present standard features like automatic focus, automatic video stabilisation, exposure controls, optical image stabilisation and even slow motion and time-lapse [Apple Inc 2014] [Samsung Inc 2015]. Currently available apps add increased func-

tionality and control over a shot allowing the user to control focus, resolution, colour balancing and many other technical elements, [Cinegenix LLC 2012]. The quality of the optics on mobile cameras is also improving and additional lenses that can be mounted on smart-phones are now commercially available [Schneider Optics 2015]. However, tools that allow professional users to access and display the accurate information they need to control the technical quality of their filming and make informed decisions about the scenes they are filming is missing on mobile platforms.
In this paper the Mobile Acquisition and VISualisation (MAVIS) app is presented. By exploiting the capabilities of modern mobile GPUs, MAVIS combines the image analysis given by professional equipment with the agility of mobile phones. Thanks to the extra information that MAVIS displays, the user is able to make informed decisions about how to light a scene and on how to set up a shot to obtain the best possible result from the mobile camera.
In the remainder of this paper an overview of the app and of its development process will be presented followed by a discussion of the shaders used by MAVIS. The MAVIS user interface will also be analysed and the additional functionalities will be discussed. Finally results from user testing will be presented and discussed.

2 App Overview

MAVIS integrates the functionalities of a vectorscope, waveform monitor, false colouring and focus peaking monitors together with all the standard functionalities of a video recording app into a single tool. The vectorscope, waveform monitor, false colour and focus peaking visualisations are necessary for professional shooting because human perception of colour and light change depending on a number of factors. For instance colour is affected by the illumination of the room or other colours present in the surrounding environment. These visualisations help to better analyse and evaluate the colour and exposure of a shot. In particular the colour vectorscope enables more accurate white balancing and gives information about colours which may be hard to perceive by just looking at the preview screen. The waveform monitor and the false colouring visualisations give information about the exposure of the shot allowing the director to make informed decisions on how to set up any lighting used within scene. Exposure can also be hard to perceive on a mobile screen and the waveform monitor, together with the false colour monitor, gives the information necessary to obtain a correctly exposed shot. Finally the focus peaking visualisation helps to determine which parts of the shot are truly in focus. On a mobile app this information is even more important as the size of the screen is reduced and it is difficult to determine which elements are in focus.

3 Development Process and shaders implementation

The app development went through a number of phases that helped determine the key functionalities missing from the apps currently available on the market, the platform on which to develop the app and the best layout of the user interface.
The decision about which platform to use was mainly influenced by the GPU capabilities of the mobile phones on which the platform runs. The Android platform was discarded due to the disparity of hardware on which it runs, making optimisation of the app harder.
By contrast, the Apple family of products presents GPU capabilities which are consistent between different devices, making development for the platform easier to address. For this reason and for the high quality camera hardware implemented on Apple devices the chosen platform for development was iOS8 targeting the iPhone 5S and iPhone 6/6 Plus hardware.

3.1 Shaders

The core of the app is composed by five shader programs, see figure 3, which implement the key features of MAVIS. Inputs for the shaders are the Y' and CbCr textures obtained from the camera, the information in these textures is elaborated and visualised differently for each feature of MAVIS. In the reminder of this section an overview of the shaders used in each feature is given. Three of the shader programs, focus peaking, false colouring and clean video, are mutually exclusive, while the other two run continuously in the app.

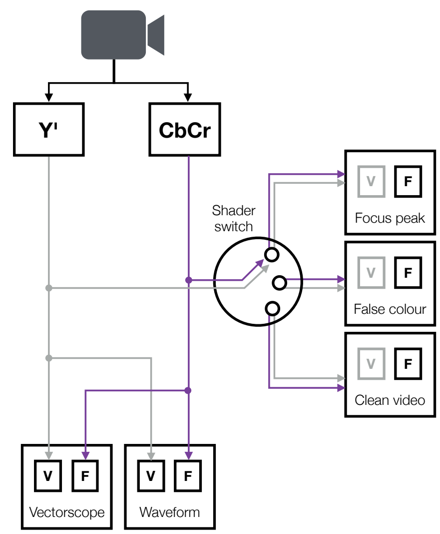

Figure 3: *Diagrams showing the flow of data from the camera to different shaders programs. V and F in the diagram stands for Vertex shader and Fragment shader respectively. The shader switch activates or deactivates a specific shader depending on the modality the user chooses to shoot.*

3.1.1 Colour-assisted waveform monitor

In order to generate the colour-assisted waveform monitor, shown in figure 4, a vertex for each texel of the Y' texture is generated, the position of each vertex is then determined for each frame by the luminance value contained in the Y' texture at that point. A vertex shader animates the vertices as the Y' values change over time as new frames arrive. The colour of the vertex is determined in the

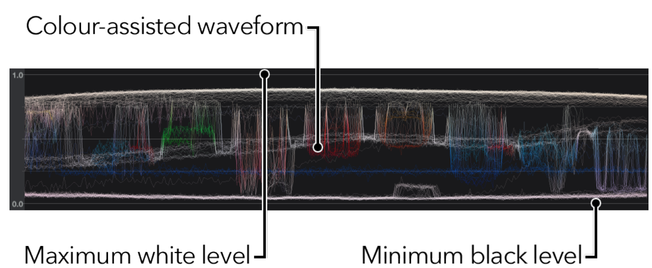

Figure 4: *Colour-assisted waveform visualization of the shot*

fragment shader in two steps. In the first step the CbCr value contained in the texel corresponding to the vertex is read and converted into HSV space. This conversion is obtained by setting the value component to 1 and the hue and saturation to the values obtained from the length and angle of the vector in CbCr space which connects the origin to the point identified by the value read from the CbCr texture. Finally, the HSV space is converted into RGB and applied as colour for the vertex.

3.1.2 Colour vectorscope

The colour vectorscope implementation is similar to the waveform implementation with the difference that this time the vertices are plotted directly into the CbCr space, as shown in figure 5.

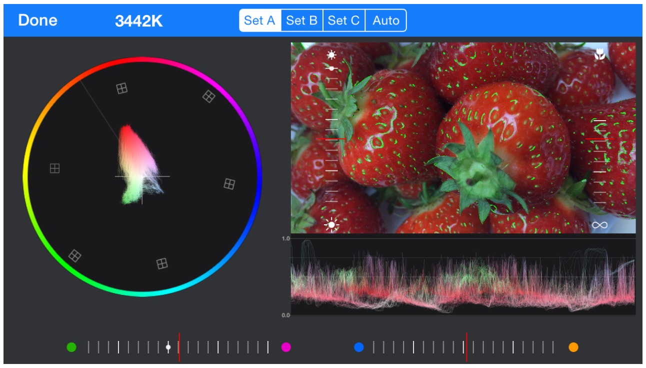

Figure 5: *White balance tool UI showing a larger colour vectorscope on the left and fluid controls towards the bottom.*

This plot needs to be then rotated by 0.19 radians to align it to the scope colours of the standard interface. Colours of the vertices on the vectorscope are again obtained by converting CbCr into HSV, with V fixed to 1, and then HSV into RGB.

3.1.3 False colouring

The false colouring functionality of MAVIS, shown in figure 6, is implemented as a fragment shader. Again the CbCr information obtained from the camera is converted in HSV, but this time the saturation and the value are set to 1 and the hue is rotated based on the information contained in the Y' texture. A conversion to RGB is then used to display the false colours. This process maps blue to minimum luma and red maximum luma.

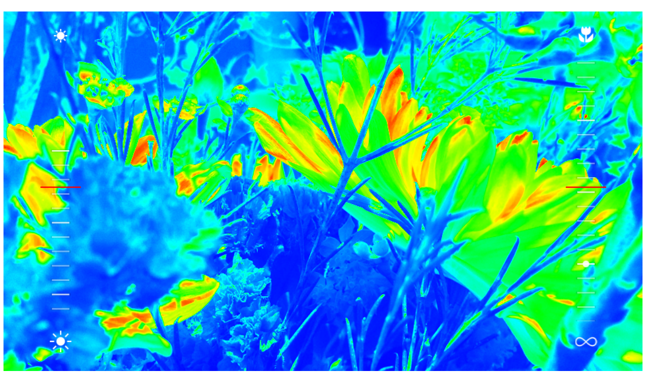

Figure 6: *False colouring functionality of MAVIS*

3.1.4 Focus Peaking

The focus peaking functionality, which is the default shader for the app, is implemented as a fragment shader using a Sobel edge detector. After the edges are identified the edge magnitude e is compared to a threshold value ε. If $e > \varepsilon$ a predetermined edge colour is shown else the original fragment colour is displayed. In our implementation we set ε to 0.1 and the edge colour to bright green, as shown in figure 7. Finally it is possible to turn off the focus peaking functionality by activating the clean video shader program which simply converts Y'CrCb to RGB and display the videos in a Rec 709 colour space.

4 User Interface

MAVIS incorporates a user interface (UI) that aims to provide the user with three main feature sets: (1) real-time image analysis visualisations, (2) intuitive manual camera controls and (3) customisable record format settings. The UI differs from other available tools in its re-prioritisation of the camera interface elements. Rather than focus the UI solely on a camera preview image, MAVIS focuses on both the preview image and real-time image analysis visualisations in the form of a waveform monitor, vectorscope, focus peaking, false colour and audio VUs.

In addition to this re-prioritisation, MAVIS also provides manual camera controls that can be manipulated while filming. These controls replicate the types of manual controls found on professional film camera such as exposure, shutter, focus and colour balance. In particular the light exposure controls and visualisation are designed to obtain, in real-time, all the information necessary to assess the dynamic range of the shot, so that shots are not over/under exposed and maximising the dynamic range from the digital camera.

Figure 7: *Calibrated colour chart seen trough MAVIS. Final MAVIS UI with focus peaking.*

The manual camera controls have been designed to mimic their analogue equivalent. The fluid motion of analogue camera dials is important while filming and this same fluid motion has been replicated into the MAVIS controls. Figure 7 shows the controls for exposure and focus control on the sides of the preview image. These controls can be manipulated while filming enabling developing shots such as focus pulls or exposure adjustments while recording. Other controls, such as shutter adjustments and colour balance, see figure 5, exploit the same fluid control motion but due to the nature of these types of controls, they are generally set-up once before recording, they are accessed via sub-menu from the side panel .

The final interface design went through various iterations. At each iteration stage a prototype interface was mocked-up and tested. Each iteration furthered our understanding of how to display each visualisation and how best to prioritise each interface element. Some of the iterations are sown in figure 8.

Figure 8: *Interface mock-ups showing the evolution of MAVIS UI*

5 Additional Functionalities

In addition to the real-time image analysis visualisations and fluid controls, MAVIS also provides additional functionalities, see figure 9.

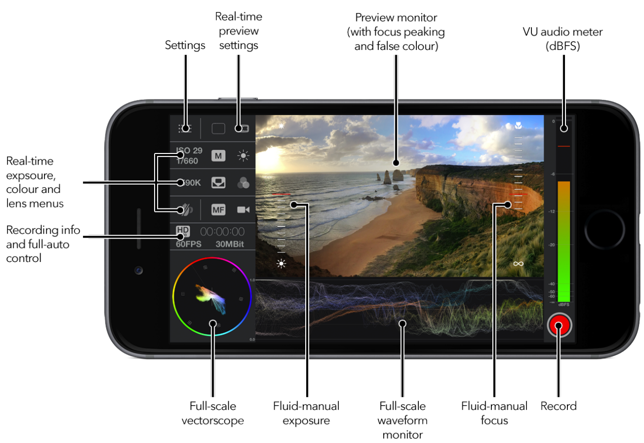

Figure 9: *Functionalities of MAVIS*

Recording resolutions that can be selected include 4K, 2K, 1080p and 720p. The recording frame rate depends on the recording resolution and can vary from 2 to 30 fps when recording at either 4K or 2K, from 2 to 60 fps when recording in HD 1080p and from 60 to 240 fps when recording in HD 720p. In 4K mode MAVIS supports the iPhone's maximum 4:3 aspect ratio output resolution. However, to better reflect the industry standard in video equipment the preview image displayed via the UI only supports images in a 16:9 aspect ratio. To compensate MAVIS crops the top and bottom of the frame in the preview, thus transforming 4:3 into 16:9. This difference between the output aspect ratio of the video and its preview provides benefits to the end user as it gives access to the highest resolution image the camera is capable of supporting, which can be useful if a shot needs to be re-framed during post production.
To provide the highest possible output quality the bit-rate of recordings can be increased to a maximum of 50Mbit per second. However, due to the large file size this level of quality produces, additional bit-rates of 10Mbit, 20Mbit and 30Mbit per second can also be selected. Due to hardware restrictions with the iPhone MAVIS can only produce H.264 encoded video files.

6 Testing and Deployment

The app was deployed on the Apple app store in April 2015 and after a month with no marketing thirty users have purchased it. Those users were asked to send feedback on MAVIS via e-mail and five of them replied to the request. In general the users who replied were professional film-makers that plan to use the app for their future short films. MAVIS was well received by the users and they especially appreciated the waveform visualiser and the focus peaking functionality which are unique to MAVIS. Another element that has been appreciated was the quality of the output that MAVIS produces. Some of the users requested to see battery and storage information, the option to hide the menu on the interface and some more advanced features such as choosing how to visualize false colouring (gradient versus range based) and some form of dynamic range boosting.

7 Conclusions and Further work

In this paper the Mobile Acquisition and VISualisation (MAVIS) app has been presented. MAVIS is a tool for professional video recording on a mobile platform which allows the user to make informed decisions about the shot by displaying a number of image analysis visualisations. This is achieved through a GPU implementation of a colour vectorscope, a colour-assisted waveform monitor, a false colour tool and a focus peaking tool. MAVIS allows professional recording of videos on a mobile platform in different formats from HD to 4K at different frame rates. As the users study shows, the app presents innovative features which were not addressed before by any app commercially available. Although MAVIS achieves good results in terms of performance, it has some limitations in the video formats that it can produce as the current state of the art of mobile platforms do not allow access to the RAW sensor data. We hope future generations of mobile devices provide this functionality. Another limitation is that as the camera returns the Y', i.e. the gamma corrected luminance, the gamma has been set in hardware and there is no control over it. Again future generation of mobile devices may allow better control over this feature. The false colour functionality can also be improved to provide alternative false colour visualisations, i.e range false colouring. To this end false colouring based on a ranged scale will be implemented in the next iterations of MAVIS.

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